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Modeling Atmospheric Scatterers Using Spacecraft Observations

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During the past year, work has centered on preparations for Galileo's arrival at Jupiter in December 1995. Two separate activities were pursued — the study of Hubble Space Telescope images of Jupiter obtained in February 1995 and the development of procedures for extracting information on the physical properties of scatterers in Jupiter's atmosphere from Galileo Probe Nephelometer data.

In February 1995 and again in October, a group led by Reta Beebe at New Mexico State University used the Wide Field/Planetary Camera 2 on the Hubble Space Telescope (HST) to obtain ~100 images of Jupiter in filters ranging from the near ultraviolet (255 nm) to the near infrared (953 nm), including a methane band filter at 890 nm. These images were studied to provide insight into the structure and dynamics of the atmosphere near the Galileo probe entry latitude of 6.5°N, since it was known that imaging data from the Galileo orbiter would be severely limited by the unusable High Gain Antenna. (In fact, problems with the on-board tape recorder prevented the return of any imaging data taken during the approach to Jupiter, so the HST images from October and another set to be obtained in February 1996 will remain our best visible and near infrared data set for the time of Probe entry.)

The images were photometrically calibrated by adding the intensities of all the pixels in each image to find the integrated disk brightness, which was then compared with published values of the disk brightness at a phase angle of 10° (Karkoschka 1994; Wallace *et al.* 1972). Calibrations derived in this manner generally agreed with those obtained from the HST "pipeline" processing to within 10%, but there were larger discrepancies at 255 nm and in the 890 nm methane band filter which have still not been entirely resolved. Details of the calibration process were distributed in a memo to members of the HST observing group.

Once the images had been photometrically calibrated, specific intensities at 890 nm and 953 nm were measured for a number of bright and dark albedo features at the probe entry latitude. These were then compared with the predictions of a simple reflecting layer model having the known molecular composition of Jupiter's atmosphere. These calculations indicate that the scattering optical depth reaches unity at a depth of 300-500 mbar for both bright and dark albedo features However, none of the features examined corresponded to a 5-μm hot spot (see below), so the applicability of these results to the actual Probe entry site is still uncertain. These results were reported at the 1995 meeting of the Division for Planetary Sciences of the American Astronomical Society (Rages 1995).

The Galileo Probe entered Jupiter's atmosphere on December 7, 1995 and returned data for 57 minutes, down to a pressure level of about 20 bars. One of the instruments carried on the probe was a nephelometer intended to measure the scattering properties of the regions the Probe passed through by detecting light from a 904 nm laser that had been scattered through angles of 5.8°, 16°, 40°, 70°, and 180° (direct backscattering). In preparation for the probe entry, software was developed to use this data to determine the particle size and number density of the scattering layers the Probe passed through. It might also be possible to determine something about the shape of the scattering particles (spherical vs. non-spherical→liquid vs. solid) and their refractive index, which would in turn place very useful constraints on their chemical composition.

The Galileo Probe entered Jupiter's atmosphere near the edge of a 5-μm hot spot, a region where the atmosphere is much clearer than on most of the planet. The Probe instruments were turned on almost a minute later than planned, so the Probe nephelometer data begins at about 300-400 mbar — near the base of the ammonia cloud, if any — instead of near the ammonia cloud top at 100 mbar as planned. Furthermore, the Probe's thermal contact with the surrounding atmosphere was far better than had been estimated when the instruments were designed, so the nephelometer temperature exceeded its design limits (in both directions!) during the descent. Analysis of the instrument's response to the unpredicted extremes of temperature is still in progress.

The nephelometer definitely saw one thin cloud at about 1.5 bars, and very preliminary analysis indicates that this cloud is composed of particles with mean radii of 1-5 μm. Figures 1-2 show the results of a least squares fit of a conservatively scattering spherical particle model to the data currently available for two different levels within this cloud (plot at top right). The best fitting values of the volume scattering coefficient β_{scat}, the real part of the refractive index n_r, the width of the log-normal particle size distribution σ, and the scattering particle radius are given at the top left, together with estimates of their uncertainty. Only the scattering at 5.8°, 16°, and 180° has been properly reduced to date. The other two channels still have unresolved anomalies in their baseline counts, presumably caused by the unforeseen temperature regime. The plots in the lower part of the figures show the scatter in each pair of free parameters, obtained by adding an appropriate amount of Gaussian noise to the three known data points, redoing the least squares fit, noting the new values of the free parameters, then repeating the process 99 more times.

As seen in Figs. 1-2, the three data points currently available can be fit by spherical scatterers having radii of 0.8 μm and a refractive index around 1.5, or by scatterers with radii around 4-5 μm and very low refractive indices ($\lesssim$1.2). The high-n_r solution is favored by the fact that very few compounds which could reasonably be found in Jupiter's atmosphere have refractive indices as low as 1.2. Data from the other two channels will be needed to make any definite estimate of the refractive index and to say with any certainty whether or not the particles in this cloud are spherical. The cloud optical depth appears to be somewhat in excess of 2, over a vertical distance of ~20 km. Preliminary results of the nephelometer data analysis have been submitted for publication in *Science* (Ragent *et al.* 1996).

Figure 1.

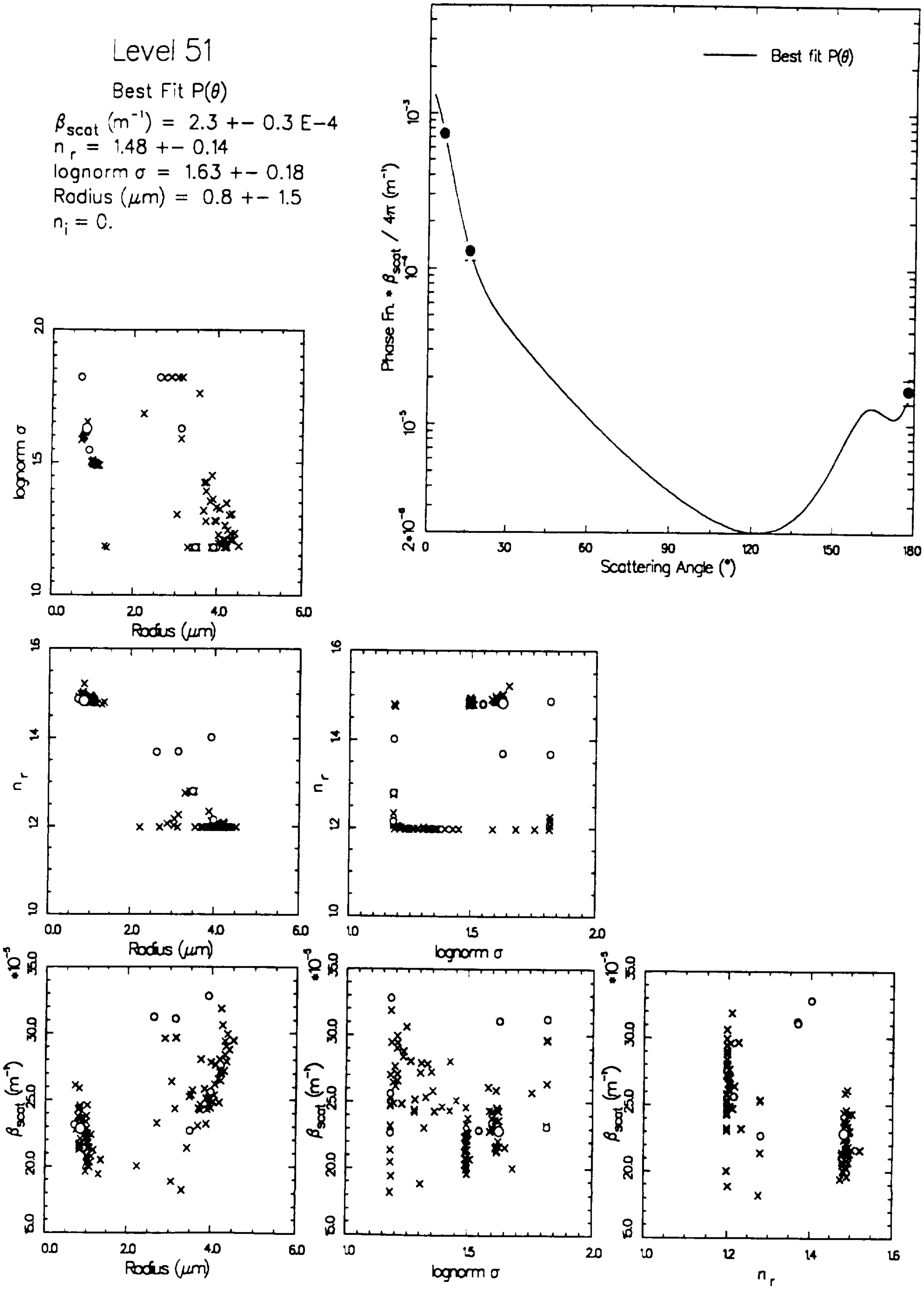
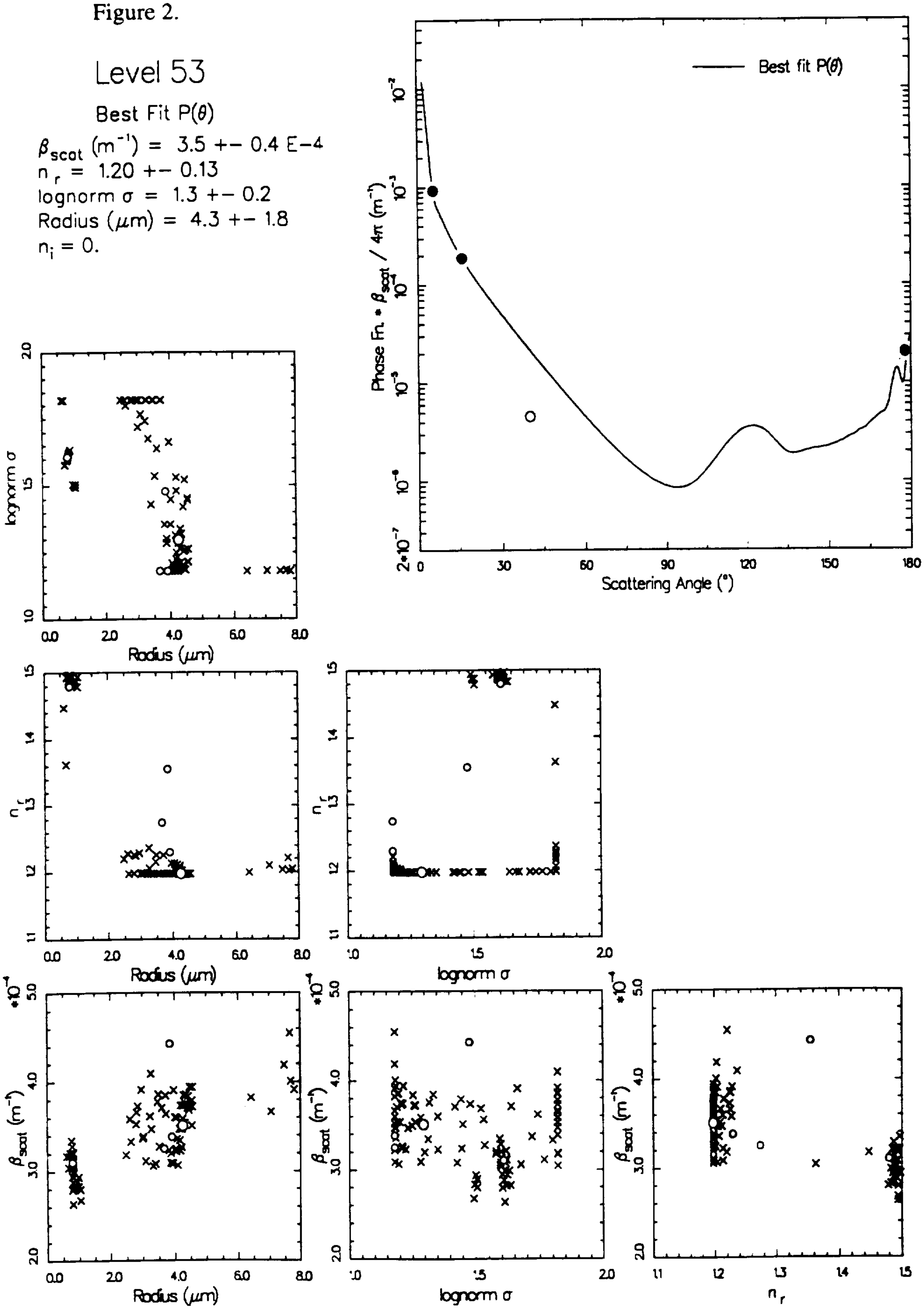

Level 51
Best Fit P(θ)
β_{scat} (m^{-1}) = 2.3 +- 0.3 E-4
n_r = 1.48 +- 0.14
lognorm σ = 1.63 +- 0.18
Radius (μm) = 0.8 +- 1.5
n_i = 0.
Best fit P(θ)
Phase Fn. * β_{scat} / 4π (m^{-1})
Scattering Angle (°)
lognorm σ
Radius (μm)
n_r
β_{scat} (m^{-1})

Figure 2.



Level 53
Best Fit P(θ)
β_{scat} (m^{-1}) = 3.5 +- 0.4 E-4
n_r = 1.20 +- 0.13
lognorm σ = 1.3 +- 0.2
Radius (μm) = 4.3 +- 1.8
n_i = 0.
Best fit P(θ)
Phase Fn. * β_{scat} / 4π (m^{-1})
Scattering Angle (°)
lognorm σ
Radius (μm)
n_r
β_{scat} (m^{-1})
*10^{-4}

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